IS THE SCATTERED RADIATION INSIDE THE 2.7 MICRONS CO_2 BAND A MEASUREMENT OF THE AEROSOLS DUST OPACITY?

G. Rinaldi, (1,2), V. Formisano (1), D. Grassi (1), V. Cottini (1), N.I. Ignatiev (3,1), L.V. Zasova (3,1).

(1) IFSI-INAF, Rome, Italy, (2) CISAS, Univ. of Padua, Italy, (3) IKI-RSSI, Moscow, Russia,

Introduction:

In this work we present an extesive analisys the atmosphere quantities able to modify the radiance observed in 2.7 µm CO_2 band. This region has been indicated by several autors (Titov et al 2000) as particularly sensitive to the integreted dust content, our conclusions however that a straightforward application of these metod may result misleading.

Since today in the literature the work of Titov et al. (2000) indicate a direct relation between radiance level and aerosols dust opacity (at 2.7 µm). If it is true, PFS data would indicate that an extremely high dust opacity is observed in the northem summer season (L_s= 90°) (Fig. 2).

Smith (2004) reported the seasonal and latitudinal dependence of water ice clouds and dust optical depth obeserved by TES. The most prominent features for the water ice is the clouds belt that extends from 10° S to 30° N latitude between L_s = 0° and L_s = 145°. This aphelion-season cloud belt was prominent at all longitudes with enhancements over regions of high topography such as Tharsis and Elysium. The optical depth in this period ranging from 0.06 to 0.12 at 825 cm^{-1}. About the dust the principal features are two dust storm. The dust storms vary greatly both in amplitude and in timing. This season was also observed during MGS aerobraking and there were dust storms at *Ls* = 225° and *Ls* = 330° similar in magnitude. This indicates that the periods near *Ls* = 225° and *Ls* = 330° may be preferred times for enhanced dust activity. The optical depth in this period ranging from 0.4 to 0.2 at 1075 cm^{-1}.

The synthetic spectra presented here demonstrate for different conditions that high altitudes water ice clouds can significantly contribute to the observed radiation level. Also the vertical profile of dust (exponential versus high altitude dust layers) can change drammatically the observed signal.

The results from our calculation, and their comparison with PFS data, indicate that in the northem summer we have to consider type II dust / water ice particles of size up to 3-4 µm. Our poor modeling of radiance slope inside the 2.7 µm CO_2 band indicate the need to change dust composition.

Synthetic Spectra:

Synthetic spectra were computed using ARS code (N.I. Ignatiev et al., 2003). This program is a set of programs implementing line by- line calculations of gaseous and aerosol opacity, transmittance and radiative transfer computations for LTE conditions.

The atmospheric model is T(p) profile values retrived according the methods presented by Grassi et al.(2005) The algorithm takes advantage of a specific subroutine for the computation of synthetic spectra able to take into acconunt the effects of multiple scattering by atmospheric aerosols .

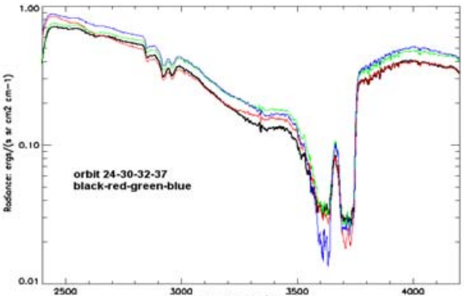
We use the solar spectrum from Fiorenza and Formisano (2005). The zenith angle of incident solar light is equal to 31° and that of the autgoing radiation is equal 14°. A surface temperature of 275 K and surface albedo of 0.2 was used in all numerical calculations.

The parameters of $C0_2$, H_20 and C0 spectral lines were taken from the Hitran data base (Rothmann et al 1992).

The **aerosols model** are defined according several parameters: (1) the particle size distribution (Clancy and Wolff 2003) (Table 1), (2) optical constant: Ockert-Bell et al. (1997) for the dust and Wolff et al. (2003) for the ice, (3) vertical distribution was asumed to be distributed both exponentially with a scale height of approximately 10 km in agreement with observations (Chassefiere et al 1995) and a uniform layer at different altitude (cloud) of about 4 km thickness.

aerosol	size distribution	R_eff (µm)	ν_eff (µm)	Particles type
dust	log-normal	1.41	0.51	
ice	log-normal	1.18	1.36	I
		2.76	1.36	II
		2.00	1.36	III

Tab 1: size distribution and aerosol size



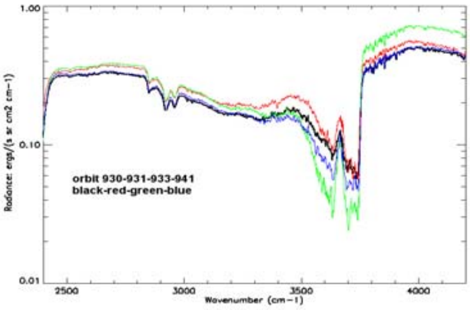


Fig.1 (up) , 2 (down)

Effect of surface pressure

These synthetic spectra were computed using different surface pressure and radiative transfer model without aerosol.

The surface pressure produce significant effects on the shape of the band: the radiance level at the bottom of the band increases and the wings of the band become more and more narrow when the P_0 decrease.

These simulation allow us to consider when the band is saturated in Martian condition and from the numerical simulation we see that at P_0 = 4 mbar the radiance level is equal to 10^{-4} which we can consider saturation level for our NER level. (Fig. 3)

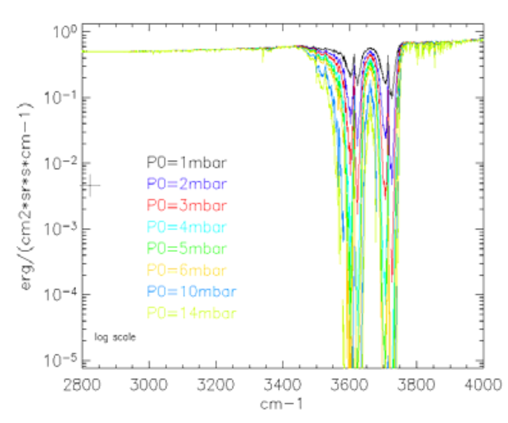


Fig 3

Effect of dust

To analyse the effect of dust in the Martian atmosphere we have computed a few synthetic spectra with different dust profile: These synthetic spectra were computed using radiative transfer model with scattering and dust aerosols.

Exponential profile

If the dust quantity increases, the radiance inside 2.7 µm band increases too and between 3200 and 4000 cm^{-1} the radiance decrease slowly, this depends on the optical constants used for the description of dust, and may not necessarily be always true (Fig.4).

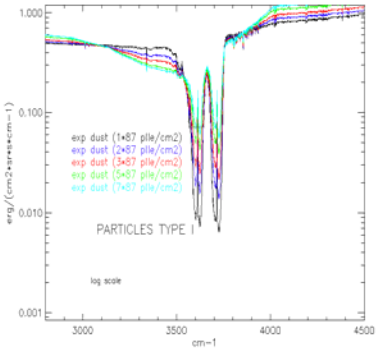
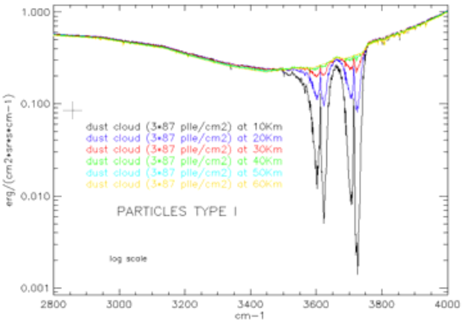


Fig 4

Cloud

If we fix the amount of dust and we describe it as a cloud at different altitudes, we can see a strong variation of radiation inside the 2.7 µm band, while the wide band (3200-4000 cm^{-1}) remains the same, this depends only on the integrated amount of dust, and not on its altitude.



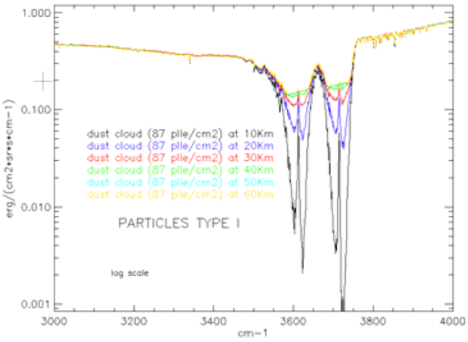


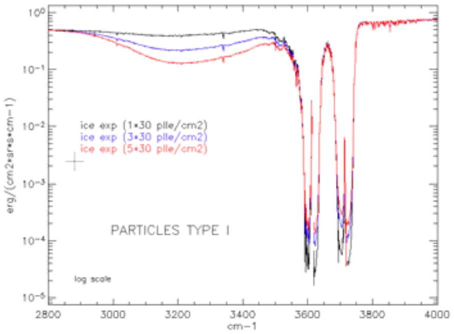
Fig. 5 (up) ,6 (down)

Effect of water ice

Also to understand the behavior of water ice in the Martian atmosphere we computed the synthetic spectra using radiative transfer model with scattering and ice aerosols.

Exponential profile

Exponential profiles of different amount of water ice have been studied (Figures 7,8). We note that different amounts of ice grains can increase the 2.7 µm radiation, although less efficiently than the dust. On the other hand , also water ice aerosols have a wide band (hydratation band) between 3000 and 3600 cm^{-1}. It is clear that water ice with constant mixing ratio in the atmosphere can hardly give a radiation level higher than 10^{-3} inside the CO_2 band. In the next study we change the size of the ice particles (Figure 9), we can see the dramatic effect of changing water: the fresnel peak appears at 3250 cm^{-1} (not present before, and present in the data).



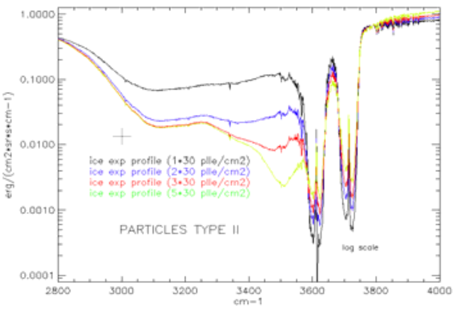


Fig. 7 (up) ,8 (down)

Cloud

These synthetic spectra were computed using radiative transfer model with scattering and ice aerosols If we consider the water ice as a cloud of 4 Km thickness at different heights, we obtain the results shown in Figures 9,10,11,12. A fixed amount of water ice can give a much higher radiation level if it is considered as a cloud , instead of a uniform mixing ratio.

Values up to 0.05 are reached. (Fig. 11, 12). Also here we can see the Fresnel peak (3250 cm^{-1}) when we have type II particles (Fig. 11, 12)

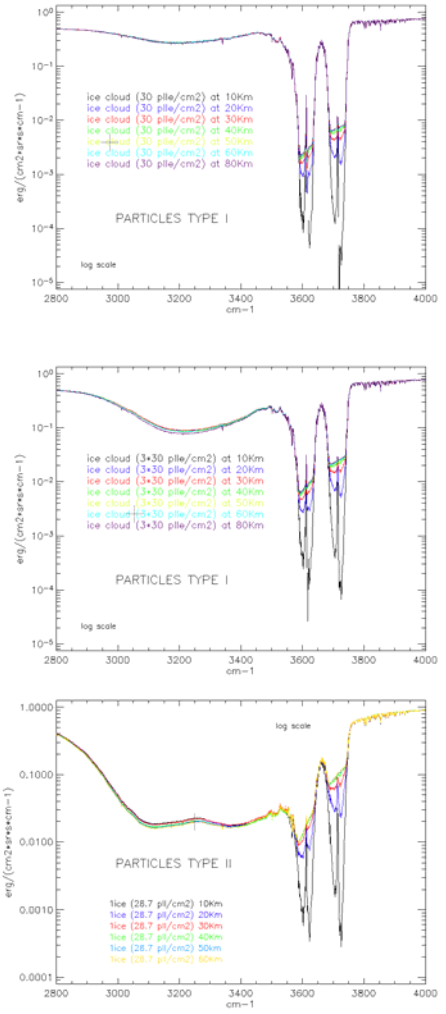


Fig. 9 (up) ,10 (middle), 11 (down)

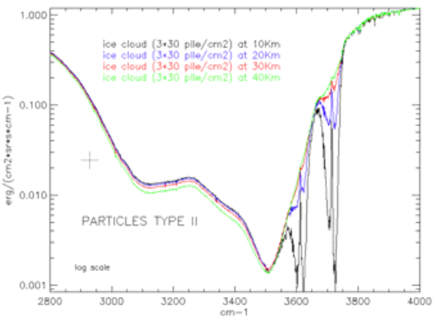


Fig. 12

Effect of dust and water ice aerosols

We have the dust and ice clouds at the same altitude but with different amount of the particles.

For the ice clouds we used different particles type (type I,II,III)

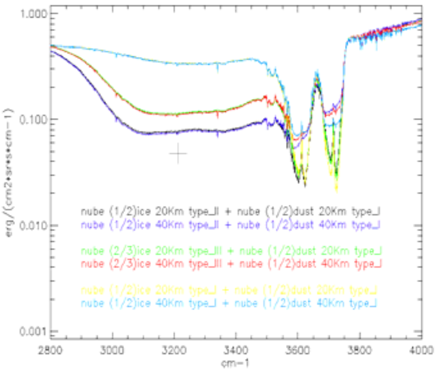


Fig. 13

Conclusion

The results from our calculation, and their comparison with PFS data, indicate that in the northern summer we have to consider type II water ice particles of size up to 3-4 µm and type I dust particles. In the southern summer, instead, we have to consider type I water ice particles and type I dust particles. But, in both cases, the radiance slope inside the 2.7 µm CO2 band indicates the need to change dust composition.

References

Titov, D. V., Fedorova, A. A., Haus, R.; A new method of remote sounding of the Martian aerosols by means of spectroscopy in the 2.7 µm CO2 band, Planetary and Space Science, Volume 48, Issue 1, p.67-74, 2000;

Wolff, M.~J. and Clancy, R.T., Constraints on the size of Martian aerosols from Thermal Emission Spectrometer observations, Journal of Geophysical Research (Planets), 2003;

Clancy, R. T., Wolff, M. J., Variations in aerosol particle properties for Mars ice and dust clouds, abstract in International Workshop on Mars atmosphere, modeling and observations, Granada, January 13th-15th 2003;

Ockert-Bell, M. E., et al.; Absorption and scattering properties of the Martian dust in the solar wavelengths, Journal of Geophysical Research, Volume 102, Issue E4, pp.9039-9050, 1997;

Grassi, D. and Ignatiev, N.I. and Zasova, L.~V. and Maturilli, A. and Formisano, V. and Bianchini, G.~A. and Giuranna, M., Methods for the analysis of data from the Planetary Fourier Spectrometer on the Mars Express Mission Planetary and Space Science, Volume 53, Issue 10, p. 1017-1034;

Ignatiev, N. I., Grassi D., Formisano, V. A simple algorithm for speedup of radiative transfer computations in planetary atmospheres with multiple scattering codes. Manuscript in preparation. (2003);